CERUSSITE
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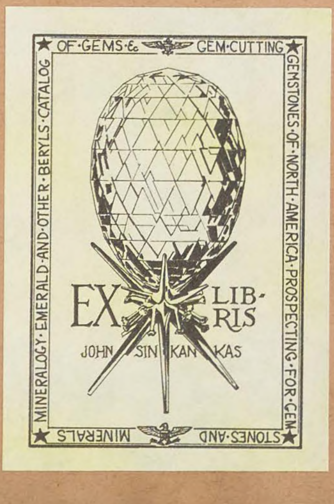
CERUSSITE CRYSTALS FROM BROKEN HILL, NEW SOUTH WALES AND MULDIVA, QUEENSLAND.

By C. ANDERSON, M.A., D.Sc., *(Edin.)*
Mineralogist to the Australian Museum, Sydney.

(Contribution from the Australian Museum.)

With Plates LII – LIV, and Six Text-figures.

[*Read before the Royal Society of N. S. Wales, November 3, 1915.*]



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CERUSSITE FROM BROKEN HILL.

OF the mineral species found in the oxidised zone of the Broken Hill lodes none are better developed or more characteristic than cerussite; indeed anyone with a little experience can at once distinguish the cerussite of Broken Hill from that of any other locality. Short descriptions of the mineral have been published by Mügge,[1] and Spencer,[2] and a fairly detailed account by Marsh.[3] Some years ago, a paper in which crystals of cerussite from Broken Hill were described, appeared in the Records of the Australian Museum,[4] but since that time the Trustees have acquired some fine specimens in the collection of Mr. George Smith and from the Dixson (formerly the Aldridge) collection, and I am now in a position to supplement the previous account, and to clear up some points which were formerly obscure. In the interval I have obtained from the authors reprints of the important papers by Goldschmidt on the cerussite of Mapimi, Mexico,[5] and by Hubrecht on the cerussite of Sardinia,[6] and am therefore able to compare

[1] Mügge, N. Jahrb. Min. II, 1897, p. 78.
[2] Spencer, Min. Mag., XIII, 1901, p. 39, f.n.
[3] Marsh, Trans. Austr. Inst. Min. Eng., IV, 1897, pp. 141 - 147.
[4] Anderson, Rec. Austr. Mus., VI, 1907, pp. 407 - 410.
[5] Goldschmidt, N. Jahrb. Min. Beil.-Bd. XV, 1902, pp. 562 - 593.
[6] Hubrecht, Zeits. Kryst., XL, 1905, pp. 147 - 188.

the crystallographic features and the complicated twinning of the three occurrences. The cerussite was found on the roof, sides, and floor of vughs in the ore masses, associated with manganic iron oxide, anglesite, smithsonite (zinc carbonate), embolite, and galena; in some specimens small crystals of galena are seated on the cerussite, indicating that the former results in these cases from secondary deposition. In habit the crystals vary somewhat. Simple crystals are rare, twins being the rule with *r* (130), or *m* (110) as twin plane. When doublets occur they are, so far as I know, always twinned on the *r* law and the crystals are either of arrow-head shape (Plate LIV, fig. 1),[1] or prismatic along the vertical axis.[2] A group of arrow-head twins scattered on a matrix of oxide of iron (Plate LIV, fig. 4) forms a specimen of rare beauty; it will be observed that the crystals are generally attached to the matrix by the point of the 'arrow.' The reticulated or dendritic groups, which are the commonest of all, and which may be described as tabular on *b* and elongated parallel to the a axis (Plate LIV, fig. 2) are combinations of twins on *r* and on *m*, and may consist of a dozen or more individuals, forming a polyet[3] of a complicated nature. The present paper is mainly concerned with the elucidation of the interesting features presented by these polyets.

Measurements were made on a Goldschmidt two-circle goniometer, which is well adapted for the investigation of complicated groups such as are here described. Measurement is greatly facilitated by the fact that the vertical axes of the several individuals (segments) composing the polyet are parallel, so that all necessary angular determinations can be readily made with one mounting of the group

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[1] Anderson, *loc. cit.*, pl. lxxvii, figs. 1, 2. [2] *Id.*, *ibid.*, pl. lxxvi, fig. 3.

[3] I am not certain whether this term has previously been used for a group of several twinned crystals, but an English equivalent for the German '*vielling*' is necessary, and polyet seems a suitable word.

on the goniometer. To discover the twin relations of two or more segments it is sufficient to determine the relative positions of the zone [*c b*] in the various segments; this zone is fortunately the best developed, and, in most cases an average of several measurements can be obtained. The orientation is most conveniently given by fixing the relative positions of the normals to *b* in each segment, that is by comparing ϕ_o of the individuals with reference to a 'first meridian.'

For twins on *m* the angle between the *b* pinacoids is 62° 46′ or 117° 14′ (180° − 62° 46′), for twins on *r*, 57° 18′ or 122° 42′. It will be noticed that these angles approach 60°, the means being 60° 2′ and 119° 58′ respectively. Now Goldschmidt and Hubrecht found (*loc. cit.*) that the angles between the twinned segments do not in every case conform to the theoretical requirements, but show a slight divergence, so that the angle between the two segments approaches more nearly to 60°, that is the angle between *m* doublets decreases and between *r* doublets increases. Goldschmidt sees in this a proof that the zone planes are planes of force (*Kraftebene*), and the face-normals directions of force (*Kraftrichtungen*), which endeavour to place themselves in parallelism much as the magnetic needle places itself in the magnetic meridian. Thus Goldschmidt says (*loc. cit.*, p. 583):—"By mutual diversion the meridians [*c b*] of the separate individuals of a polyet approach the positions 0°, ± 60°, ± 120°, ± 180°. The group approximates to hexagonal symmetry." Hubrecht (*loc. cit.*, p. 149) puts the matter very clearly and concisely, "This divergence [*Ablenkung*] was regarded as an argument in favour of the view that face-normals are directions of force which bind the particles together and unite crystals in parallel or twin position, that moreover zone planes are to be regarded as planes of force, and that such directions of force and planes of force influence one another when they have nearly

the same direction and that in this case they endeavour to take a middle position." Goldschmidt then, and following him Hubrecht consider that twinning is to be explained by the tendency of lines and planes of force in the two individuals to place themselves parallel. In Text Fig. 1,

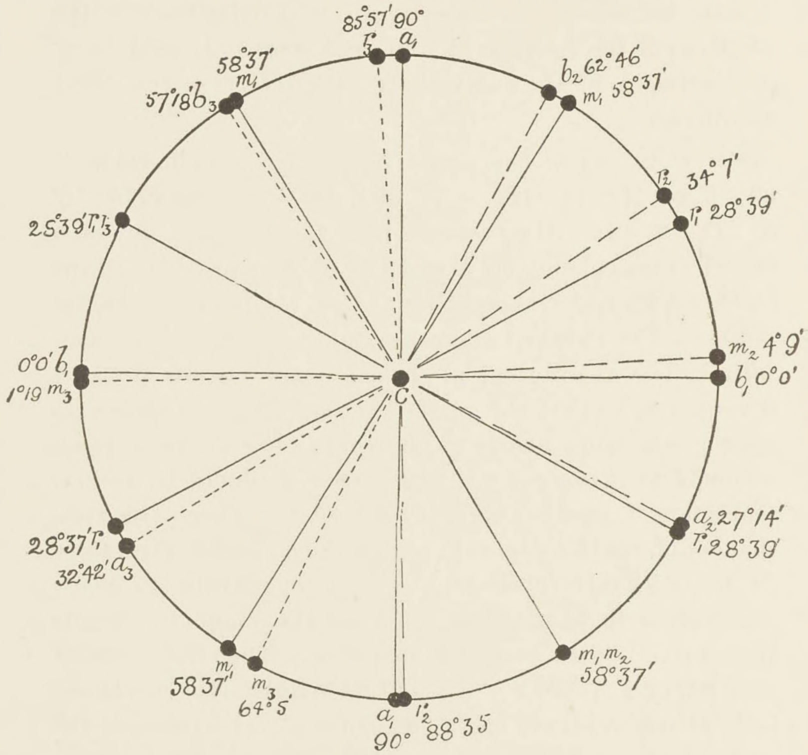


Fig. 1.

we have a stereographic projection of a cerussite crystal I in the conventional position, showing the poles of the pinacoids and the *m* and *r* prisms, the corresponding normals being drawn in full lines, with, on the right, the same poles and normals (long-dashed lines) of a crystal II twinned to I on *m* (110), and, on the left, the poles and normals (short-dashed lines) of a crystal III twinned to I on *r* (130). The

vertical axes, that is the normals to the c pinacoids, have placed themselves parallel in the three segments and in II one zone plane $[c\,m]$ and normals in that zone are ranged parallel to the corresponding plane and normals in I, while in the r twin III one zone plane $[c\,r]$ and its normals have placed themselves parallel to the corresponding plane and normals of I, whence the twin relations result. It is apparent that if II and III be rotated slightly cum-clockwise, the normals to b_2 and m_1 r_2 and r_1, m_2 and b_1, a_2 and r_1 and r_2 and a_1, also r_3 and a_1, b_3 and m_1, m_3 and b_1, a_3 and r_1, m_3 and m_1, respectively, will be brought closer together. This will have the effect of bringing b_2 closer to b_1 and separating b_3 and b_1 more widely, that is the angle $b_1 \wedge b_2$ becomes less than the precise 62° 46′ and $b_1 \wedge b_3$ greater than 57° 18′. In each case therefore the angle $b_1 \wedge b_x$ comes nearer to the value 60°. In general none of the axes will coincide but will take a 'middle position.'

Although the existence of 'planes of force' and 'directions of force' in the zone planes and face-normals is more or less an assumption, there is no doubt that crystals do possess a directive force by virtue of which the crystal particles, whatever these may be, are marshalled into a regular formation; this is proved by the existence of liquid crystals. Moreover there is nothing unorthodox in speaking of parallelism of axes or directions which are not crystallographically equivalent, for we know that crystals do exhibit parallel growths of this kind; we may cite Goldschmidt's 'hetero-twins,' in which inequivalent but similar and similarly directed axes place themselves parallel or nearly parallel.[1]

Whether Goldschmidt's hypothesis is valid or not it is important to discover whether a similar divergence to that

[1] Goldschmidt, Zeits. Kryst., XLIII, 1907, pp. 582–586; Goldschmidt and Paul, Ib., XLVI, 1909, p. 471; Ford, Amer. Journ. Sci. XXX, 1910, pp. 16–23.

observed by him and by Hubrecht is shown by cerussite from other localities. In my former paper (*loc. cit.*, p. 409) I gave the result of measurement made on two groups of four crystals twinned in pairs on r. "Denoting the four segments by I, II, III, IV, we have I and II, likewise III and IV twinned on r, but although the orientation of III and IV relative to I and II is nearly the same in the two groups, I have not been able to prove it due to twinning on any known face. Appended are the angles obtained between the b pinacoids of the four segments.

(1) $b_1 \wedge b_2 = 57^\circ\ 13'$ (calculated for r-twin $57^\circ\ 18'$)
$b_1 \wedge b_3 = 61\ \ 26$ (calculated for m-twin $62^\circ\ 46'$)
$b_1 \wedge b_4 = \ \ 4\ \ \ 4$

(2) $b_1 \wedge b_2 = 57\ \ 18$
$b_1 \wedge b_3 = 61\ \ 54$
$b \wedge b = \ \ 4\ \ 38$"

At the time this was written I had not seen the papers by Goldschmidt and Hubrecht and was not aware that these crystallographers had observed divergences of the same order, and it is one of the objects of this paper, now that better material is available, to extend the investigation in order to see if possible whether any general rule covering these anomalies applies to the cerussite of Broken Hill and Muldiva, where similar polyets are found. It may be remarked that a departure from the exact angle demanded by the twin law has been observed in other minerals than cerussite; thus Des Cloizeaux[1] found that in albite twins faces theoretically parallel may be inclined to one another at an angle varying from 40′ to 1° 40′, and Miers[2] observed a similar variation in twins of proustite and pyrargyrite.

Description of Groups.

Group I. (Plate LIV, figs. 5, 6).—This specimen from Block 14, is a triplet on r, II and III being twinned to I;

[1] Des Cloizeaux, Man. de Minéralogie, I, p. 520.
[2] Miers, Min. Mag., VIII, 1888, pp. 74—76.

it is too large for measurement on the reflecting goniometer, I, which is elongated parallel to *b*, being 9 cm. long by 5 cm. in depth, but approximate measurements with a contact goniometer leaves little doubt as to the relations of the three segments. In Fig. 6 I is represented as lying on the *b* pinacoid, but in all other similar figures in this paper the crystals are placed with the vertical axis perpendicular to the plane of the paper as this is the best position for showing the orientation. On I is a small arrow-head twin the exact relation of which to the larger segments could not be determined; a little plumose galena is crystallised on the cerussite.

Group II (Plate LII, fig. 1, Text Fig. 2).—This and the succeeding three groups from the Proprietary Mine are off a large specimen consisting of crystals elongated parallel to the vertical axis, and measuring to about 7 by 1 cm.; the matrix is stalactitic limonite and short tapering crystals of smithsonite are attached to the cerussite. The group consists of four segments twinned in pairs on *r*, the forms present being *b* (010), *m* (110), *r* (130), *x* (012), *k* (011), *i* (021), *v* (031), *y* (102), *p* (111). The faces in the prism zone are strongly striated vertically, but the terminal faces

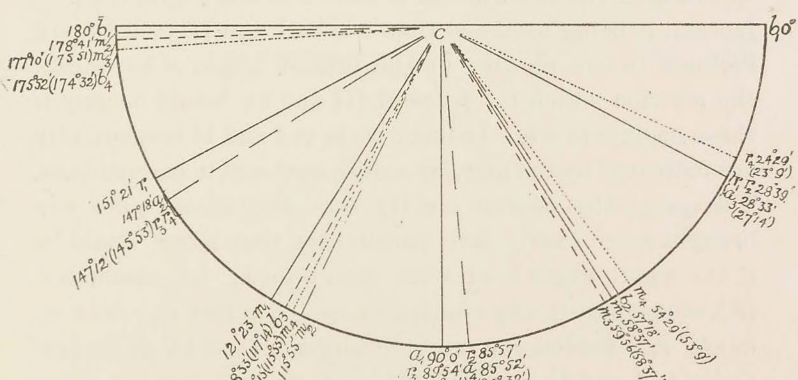


Fig. 2.

are mostly smooth and brilliant, giving good reflections. In the following and succeeding tables the best measurements, suitably weighted, are used to fix the position of the *b* pinacoid and in the accompanying text figures the orientation of the various twin segments is indicated by the position of the normal to *b*; V_o is the mean of the actual goniometric readings, ϕ_o gives the angular distance from the first meridian (position of segment I).

Segment.	V_o.	Limits.	Number of Observations.	ϕ_o
I	117° 18′	117° 16′ – 117° 22′	3	0° 0′
II	174 28	174 17 – 174 32	5	57 11
III	235 51	235 44 – 235 56	3	118 33
IV	293 10	293 10 – 293 11	2	175 52

Thus we have the following angular relations:—

I ∧ II = 57° 11′ (*r*-twin 57° 18′). I ∧ III = 61° 27′ (*m*-twin 62°46′).
III ∧ IV = 57° 18′. II ∧ IV = 61° 19′.
II ∧ III = 61° 22.

The divergence therefore from the position of an *m*-twin is in the sense demanded by Goldschmidt's hypothesis. In Text Fig. 2 the orientation is shown in stereographic projection, it being assumed that I and II and III and IV are inclined to one another at the precise angle of twinning; the position which the poles of III and IV would occupy if these segments were twinned on *m* to I and II respectively are indicated by the angular values enclosed in parentheses. This projection shows clearly that the chief zones are brought more nearly into parallelism than they would be if the exact angle $b \wedge \underline{b}$ were maintained; for example r_1 (r_2), a_3 are practically coincident as are a_4 and r_2, r_3 and a_1, a_2 and r_4. Indeed one might describe III and IV as heterotwins to I and II in which the vertical axes and the zones [c *a*] and [c *r*] are parallel.

Group III.—This is very similar to Group II and does not require particular description. The orientation is as follows:—

Segment.	V_c	Limits.	Number of Observations.	ϕ_o
I	351° 0′	350° 59′ – 351° 2′	5	0° 0′
II	48 19	48 14 – 48 26	6	57 19
III	109 5	108 59 – 109 6	5	118 5
IV	166 14	166 11 – 166 17	2	175 14

Thus I is twinned to II on r (meas. 57° 19′, calc. 57° 18′) and III to IV on r (meas. 57° 9′) while $b_1 \wedge b_3 = 61° 55'$ and $b_2 \wedge b_4 = 62° 5'$. The direction of divergence is the same as before and is in accordance with Goldschmidt's hypothesis.

Group IV (Plate LII, fig. 4, Text Fig. 3).—This is essentially similar to the two preceding groups, but the segments are united in a different manner.

Segment.	V_o	Limit.	Number of Observations.	ϕ_o
I	72° 52′	72° 48′ – 72° 56′	4	0° 0′
II	130 7	130 5 – 130 9	7	57 15
III	250 41	250 34 – 250 46	7	177 49
IV	128 0	127 56 – 128 4	7	55 8
(V				117 14)

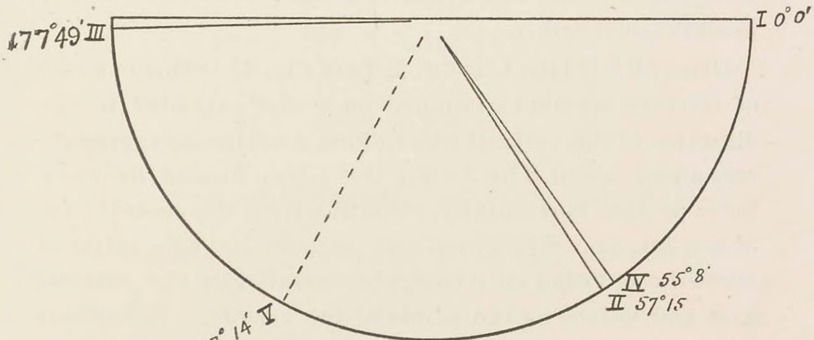


Fig. 3.

V is a hypothetical segment twinned to I on *m*; to assume its existence is permissible as the position is a possible and probable one. We then have the following relations:—

$$\begin{array}{lll} \text{I} \wedge \text{II} = 57^\circ\ 15' & \rbrace & \\ \text{III} \wedge \text{IV} = 57\ \ 19 & \rbrace & r\text{-twin } 57^\circ\ 18' \\ \text{III} \wedge \text{II} = 59\ \ 26 & \rbrace & \rbrace \\ \text{IV} \wedge \text{V} = 62\ \ 06 & & \rbrace\ m\text{-twin } 62^\circ\ 46'. \\ \text{III} \wedge \text{V} = 60\ \ 35 & & \rbrace \end{array}$$

Here again the two *r*-twins I and II, III and IV conform very closely to the theoretical angle, while III to II and III and IV to the assumed segment V (twinned to I on *m*) show the required divergence.

Group V.—In this the segments are unequally developed, I and II being much larger than III and IV.

Segment.	V_0	Limit.	Number of Observations.	ϕ_0
I	164° 21′	164° 19′ – 164° 23′	3	0° 0′
II	221 39	221 33 – 221 42	7	57 18
III	286 58	286 56 – 287 0	2	122 37
IV	281 30	281 29 – 281 30	2	117 9

In this group, therefore, I is twinned to II and to III on *r* (angles 57° 18′ and 57° 23′, calc. 57° 18′), and I is twinned to III on *m* at an angle of 62° 51′ (calc. 62° 46′), the variation from the calculated angles being within the limits of observational error.

Group VI (Plate LII, fig. 2, Text Fig. 4).—This consists of thirteen segments twinned on *r* and extended in the direction of the vertical axis to form a columnar aggregate measuring about 8 by 2 cm.; the edges formed by the *r* faces project horizontally, radiating from the central part of the column. The group may be described as a polyet of arrow-head twins on *r* elongated parallel to the vertical axis and united by the points of the arrows. Reflections are moderately good, but for some of the segments the measurements were rather meagre, and a high degree of

accuracy for the orientation is not claimed. The chief forms present are *b* (010), *r* (130), *y* (102), *k* (011), *x* (012), the two last much striated; *i* (021), *o* (112), and *p* (111) are also represented, and *m* appears as striæ in *r*.

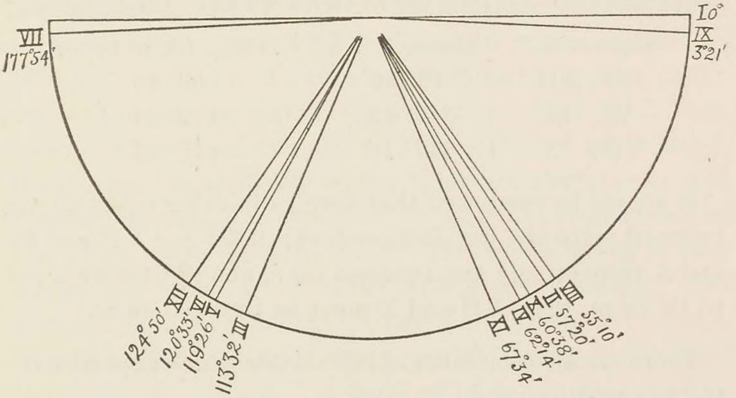


Fig. 4.

Segment.	V_o	Limits.	Number of Observations.	ϕ_o
I	316° 58'	316° 51' – 317° 3'	4	0° 0'
II	14 18	14 8 – 14 28	5	57 20
III	70 30	70 25 – 70 33	5	113 32
IV	19 12	18 48 – 19 24	5	62 14
V	76 24	76 2 – 76 40	4	119 26
VI	77 31		1	120 33
VII	134 52	134 42 – 135 3	7	177 54
VIII	192 8	192 5 – 192 11	2	55 10
IX	320 19		1	3 21
X	17 36	17 35 – 17 36	2	60 38
XI	24 32	24 23 – 24 40	5	67 34
XII	81 48		1	124 20

The *r*-twins can be easily distinguished as those tabulated below:—

Segments.	Meas. $b \wedge \underline{b}$	Calc. for *r*-twin
I, II	57° 20'	57° 18'.
IV, V	57 12	
VI, VII	57 21	
VII, VIII	57 15	
IX, X	57 17	
XI, XII	57 16	

From inspection one would be led to think that II is twinned to III on *r*, forming a triplet with I similar to the triplet VI, VII, VIII, but the angle between II and III is only 56° 12′; the angles between the others agree well with requirements. Of possible *m*-twins we have the following:

Segments.	Meas. $b \wedge \underline{b}$	Calc. for *m*-twins.
IV, XII	62° 36′	62° 46′
VI, IX	117 12	117 14
VII, X	117 16	117 14

It should be remarked that here as in other cases all the twinned pairs are not independent; if VI and VII and IX and X respectively are twinned on *r*, and if VI is twinned to IX on *m*, then VII and X must be twinned on *m*.

There are also a number of individuals which approximate to twin position:—

Segments.	Meas. $b \wedge \underline{b}$.	
I, IV	62° 14′	Calc. for *m*-twin 62° 46′
II, V	62 6	
V, VII	58 28	Calc. for *r*-twin 57° 18′
IV, VI	58 19	
X, V	58 48	
X, VI	59 55	
III, VIII	121 37	Calc. for *r*-twin 122° 42′
IX, XII	121 29	

All these diverging angles show the required variation except the angle between II and III, but where so many segments are concerned, the mutual relations are not so clear as in simpler groups; one cannot see the wood for the trees as it were. The text figure brings into prominence the fact that the crystals group themselves round directions at about 60° apart, namely 0° 25′ (mean position of I, VII, IX), 60° 35′ (mean position of VII, II, X, IV, XI), and 119° 35′ (mean position of III, V, VI, XII). We shall see later that this orientation, which shows that the grouping is not haphazard, is characteristic.

Group VII (Plate LII, fig. 3).—This and Groups VIII and IX are all portions of one large specimen, and they naturally show some family resemblance; they belong to the reticulated type, the crystals being short in the direction of the vertical axis, tabular on *b* and elongated parallel to the a axis. Group VII consists of seven individuals twinned on *m* and *r*, the angular relations conforming fairly well to the requirements of the two laws. Segment I, 5 cm. long, is larger than the others, II and III are fairly large, the others comparatively small; there are a number of still smaller individuals whose position could not be ascertained and which have been omitted. The whole group is very fragile and most of the terminations are wanting. The commonest faces belong to the forms *c* (010), *m* (110), *r* (130), *k* (011); *x* (012), *i* (021), *v* (031), *y* (102), *p* (111) and *w* (211) were also recognised. In spite of frequent striation the signals were on the whole good and the orientation of the crystals is well established. In the figure the crystals are idealised but their relative dimensions and positions are preserved. Segments which are parallel though not in contact are numbered alike and the measurements obtained from them are combined to find the mean angles given in the subjoined table.

Segment.	V_o	Limits.	Number of Observations.	ϕ_o
	° ′	° ′ ° ′		° ′
I	206 53	206 45 – 207 10	11	0 0
II	329 32	329 26 – 329 35	7	122 39
III	212 21	212 13 – 212 35	8	5 28
IV	324 9	323 59 – 324 14	8	117 16
V	269 29	269 24 – 269 34	4	62 36
VI	274 56	274 50 – 275 2	3	68 3
VII	332 4	332 2 – 332 6	3	125 11

The twins may now be readily recognised:—

Segments.	Meas. $b \wedge \underline{b}$	
I, II	57° 21′	Calc. for *r*-twins 57° 8′
III, V	57 8	
VI, VII	57 8	

Segments.	Meas. $b \wedge \underline{b}$	
I, IV	62 44	Calc. for *m*-twins 62° 16′
I, V	62 36	
II, III	62 49	
V, VII	62 35	

Thus all the segments are united by the two laws and the deviation from the exact angle of twinning is nowhere more than 11′.

Group VIII (Plate LIV, fig. 3, Plate LII, fig. 5, Text Fig. 5).—This instructive group consists of thirteen individuals, some of which are represented by several crystals in parallel position, and finely illustrates the complicated twinning and reticulated or dendritic structure of the mineral. It also exemplifies well the manner in which 'secondary' and 'tertiary' twins are apt to form in the re-entrant angle of the 'primary' twins and so to fill up this angle. The individuals I, II and III are much larger than the others, I having a length of about $5\frac{1}{2}$ cm.; these three may be described as 'paragenic' twins, that is they formed an embryonal triplet and grew up together, while the others are 'metagenic' twins which came into existence after I, II and III had attained some size. A small, typical arrow-head twin IV and V is planted on I; it has the forms *b* (010), *r* (130), *x* (012), *k* (011), *y* (102), *p* (111), *s* (121). This *r*-twin pair is not in any exact relation to the main group except that the direction of its vertical axis is the same. Two small crystals VII and XII, which are not exactly twinned to one another (angle 63° 14′, calc. 62° 46′), are attached to the IV and V pair, but, like the latter, these are not in any precise twin relation to any of the others, although VII is very nearly parallel to IX and XII to VIII; the other twin relations are well established. The drawing (Plate LII, fig. 5) is partly diagrammatic; the stippled portion in the bottom left corner of the figure belongs to a twin group whose vertical axis is not parallel to that of Group VII.

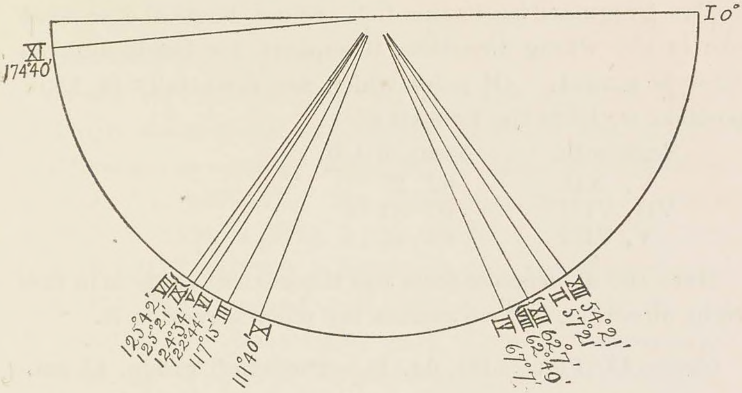


Fig. 5.

Segment.	$V_\circ$	Limits.	Number of Observations.	$\phi_\circ$
	° ′	° ′ ° ′		° ′
I	286 9	286 7 – 286 10	5	0 0
II	343 30	343 22 – 343 37	4	57 21
III	43 24	43 20 – 43 29	7	117 15
IV	353 16	353 11 – 353 28	8	67 7
V	50 43	50 36 – 50 53	6	124 34
VI	48 53	48 52 – 48 53	3	122 44
VII	51 30	51 14 – 51 46	2	125 21
VIII	348 58	348 52 – 349 6	5	62 49
IX	51 51	51 47 – 51 59	5	125 42
X	37 59	37 49 – 38 7	3	111 40
XI	100 49	100 43 – 101 4	4	174 40
XII	348 16	348 13 – 348 19	2	62 7
XIII	340 30	340 30	2	54 21

Disentangling the twins we have the following results:—

Segments.	Meas. $b \wedge \underline{b}$	
I, II	57° 21′	
I, VI	57 16	
III, XI	57 25	Calc. for r-twin 57° 18′.
IV, V	57 27	
X, XIII	57 19	
I, III	62 45	
I, VIII	62 49	
II, XI	62 41	Calc. for m-twin 62° 46′.
VIII, IX	62 53	
III, XIII	62 54	
X, XI	63 00	

The irregularities in this list are not large and several are in the wrong direction, if support for Goldschmidt's view is sought. Of pairs which are doubtfully in twin position we have the following:—

Segments.	Meas. $b \wedge \underline{b}$
V, XII	62° 27′
VII, VIII	62 32
V, VIII	61 45

Here the divergence from the theoretical angle is in the right direction, but we cannot lay much stress on it.

Group IX (Plate LIII, fig. 1).—The small group, $1\frac{1}{2}$ cm. approximately in length, has a general resemblance to the last described. Here I and V, and perhaps II, are paragenic twins, the others metagenic. The forms represented are *b* (010), *m* (110), *r* (130), *x* (012), *k* (011), *i* (021), *v* (031), *y* (102), *p* (111).

Segment.	V_o	Limits.	Number of Observations.	ϕ_o
	° ′	° ′ ° ′		° ′
I	329 9	329 6 – 329 11	6	0 0
II	32 1	31 56 – 32 7	5	62 52
III	143 38	143 37 – 143 40	5	174 29
IV	94 48	94 43 – 94 53	3	125 39
V	26 27	26 24 – 26 31	10	57 18
VI	86 42	86 41 – 86 42	2	117 33

Twin relations:—

Segments.	Meas. $b \wedge \underline{b}$	
I, V	57° 18′	Calc. for *r*-twin 57° 18′.
I, II	62 52	
I, VI	62 28	Calc. for *m*-twin 62° 46′.
II, IV	62 47	
III, V	62 49	

The segment VI is the only one which shows a noticeable departure from the true twin position; unfortunately only scanty measurements were obtained but the signals were good and 18′ is too great a discrepancy to be attributed to observational error. Crystal VI, if twinned at all, is

evidently twinned to I, and its position lends support to Goldschmidt's contention.

Group X (Plate LIII, fig. 4, Text Fig. 6).—This group, which is about 3½ cm. in greatest diameter, was attached to a limonitous matrix; in general appearance it resembles Groups VII, VIII, IX. The forms identified are *c* (001), *b* (010), *m* (110), *x* (012), *k* (011), *i* (021), *v* (031), *y* (102), *p* (111), *o* (112), *s* (121); in addition a face which may belong to *q* (023) was observed once (ρ meas. 25° 48′, calc. 25° 44′). A possible new dome (059) gave a single measurement (ρ meas. 22° 0′, calc. 21° 53′), but it requires confirmation.

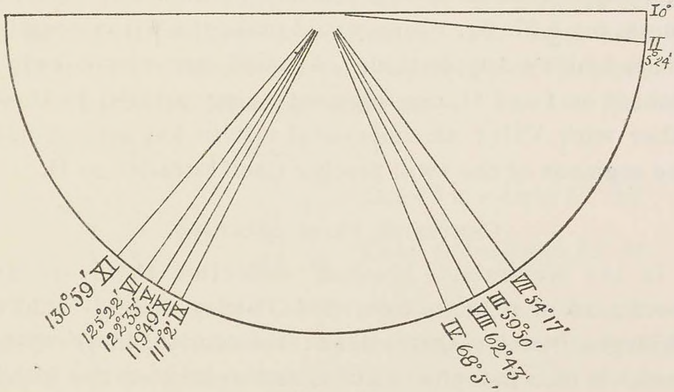


Fig. 6.

Segment.	V_o	Limits.	Number of Observations.	ϕ_o
I	116° 3′	116° 7′ – 116° 25′	10	0° 0′
II	121 37	121 28 – 121 44	8	5 24
III	176 3	176 1 – 176 5	3	59 50
IV	184 18	184 11 – 184 24	8	68 5
V	238 46	238 41 – 238 54	11	122 33
VI	241 35	241 32 – 241 37	4	125 22
VII	170 30	170 29 – 170 30	2	54 17
VIII	178 56	178 48 – 179 6	12	62 43
IX	233 15	233 3 – 233 27	11	117 2
X	236 2	236 1 – 236 2	2	119 49
XI	247 12	247 9 – 247 16	2	130 59

Twin relations:—

Segments.	Meas. $b \wedge \underline{b}$	
I, V	57° 27′	Calc. for *r*-twin 57° 18′.
II, VIII	57 19	
III, IX	57 12	
IV, VI	57 17	
I, VIII	62 43	Calc. for *m*-twins 62° 46′.
II, IV	62 41	
IV, XI	62 54	
VI, VIII	62 39	
VII, IX	62 45	

The only crystal unaccounted for in the above scheme is X; it approximates to the position of an *r* twin to VIII (meas. $b \wedge \underline{b}$ 57° 6′), which would make it a witness against Goldschmidt's supposition. A small arrowhead twin is planted on I and II, one segment being parallel to II, the other with VIII; an embryonal *r*-twin has settled on II, one segment of the twin placing itself paralled to II.

Cerussite from Muldiva.

In the Australian Museum collection there are two specimens of azurite from the Paisley Shaft, Muldiva, Chillagoe District, Queensland; the azurite, finely crystallised,[1] is on a limonite matrix, and seated on the azurite are small crystals of cerussite, many of them twinned. The cerussite groups are scarcely larger than a pin's head, but the faces give good reflections in the main, and four groups were measured with the following results.

Description of Groups.

Group I (Plate LIII, fig. 5). This is a triplet of a type common with cerussite and aragonite. The faces, idealised in the drawing, belong to the forms *c* (001), *a* (100), *b* (010), *m* (110), *r* (130), *y* (102), *p* (111). The value of ϕ_0 for the three segments is 0° 0′, 62° 41′ and 117° 18′ respectively,

[1] Anderson, Rec. Austr. Mus., VII, 1909, p. 278.

which shows that I is twinned to II and to III on *m* (calc. angles 62° 46′ and 117° 14′).

Group II (Plate LIII, fig. 2). Here the *r* law predominates, the group consisting of two arrow-head twins united by their points ; measurement however reveals that while I is twinned to II on *r* it is twinned to III on *m*, hence also IV is twinned to II on *m*, so that here we have a fine example of four individuals united by the two laws. The faces in the prism zone are so strongly striated that their readings barely suffice for identification, but the faces of *p* and *y* give good readings, so that the orientation can be relied upon to within a few minutes. The value of ϕ_o for I, II, III, IV respectively is 0° 0′, 57° 9′, 62° 30′, 119° 42 and we have the following relations:—

Segments.	Meas. $b \wedge \underline{b}$	
I, II	57° 9′	Calc. for *r*-twin 57° 18′
III, IV	57 12	
I, III	62 30	Calc. for *m*-twin 62° 46′
II, IV	62 33	

This result does not throw much light on the general question as the variations in the *r*-twins are away from 60° and in the *m*-twins towards 60°; in any case the measurements are too few.

Group III (Plate LIII, fig. 3).—This group, which is rather more complicated than the preceding two, has the forms *a* (100), *b* (010), *m* (110), *r* (130), *k* (011), *y* (102), *p* (111); the prism zone is striated vertically, *b* and *r* inter-oscillating, while *m* is very narrow.

Orientation.

	I	II	III	IV	V
V_o	102° 55′	160° 12′	165° 33′	228° 16′	225° 45′
ϕ_o	0 0	57 17	62 38	125 21	122 50.

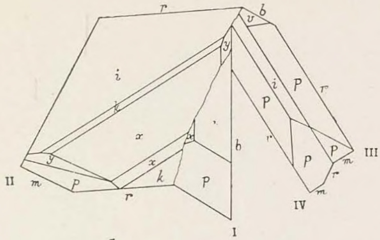
The twinning is therefore as follows:—

Segments.	Meas. $b \wedge \underline{b}$	
I, II	57° 17′	Calc. for *r*-twin 57° 18′
I, V	57 10	
I, III	62 38	Calc. for *m*-twin 62° 46′
III, IV	62 43	

and there is no marked divergence from the true twin position.

Conclusion.

Generally speaking the variations from the true twin position are in the same direction as in the crystals investigated by Goldschmidt and Hubrecht, but this is not always the case, and it is doubtful whether any far-reaching conclusion can be drawn on the basis of these observations.



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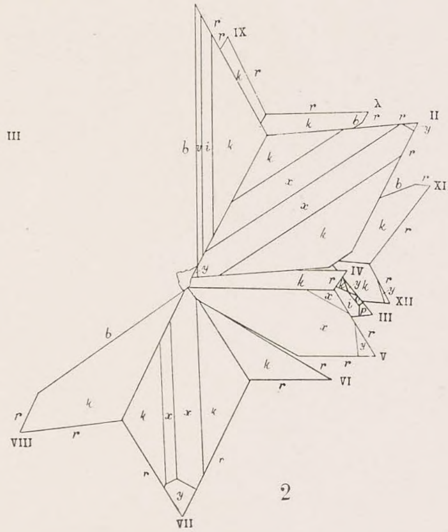

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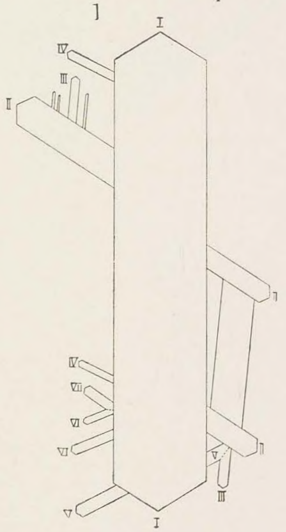

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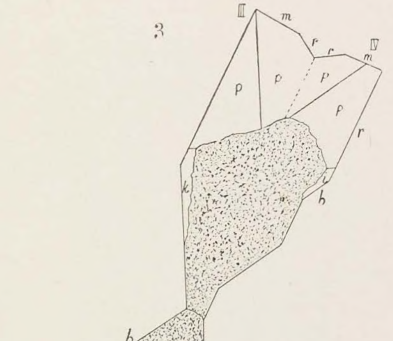

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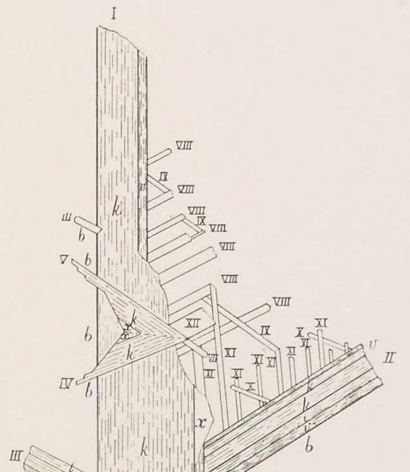

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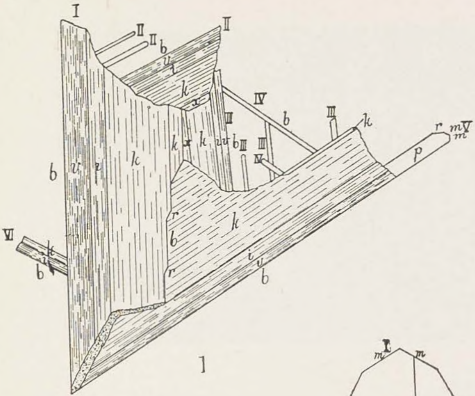

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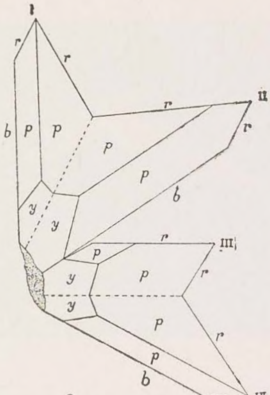

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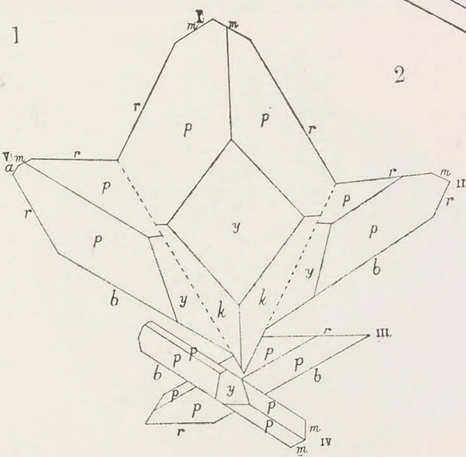

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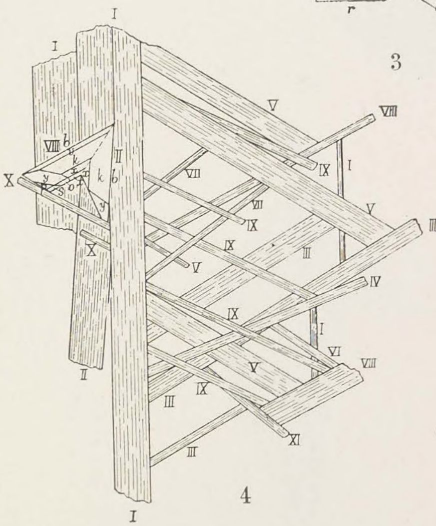

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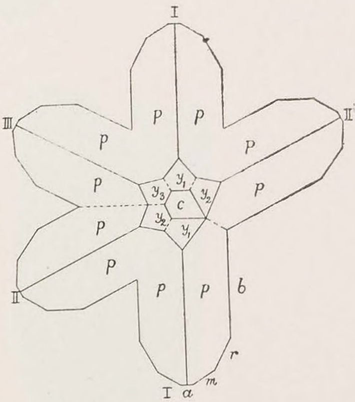

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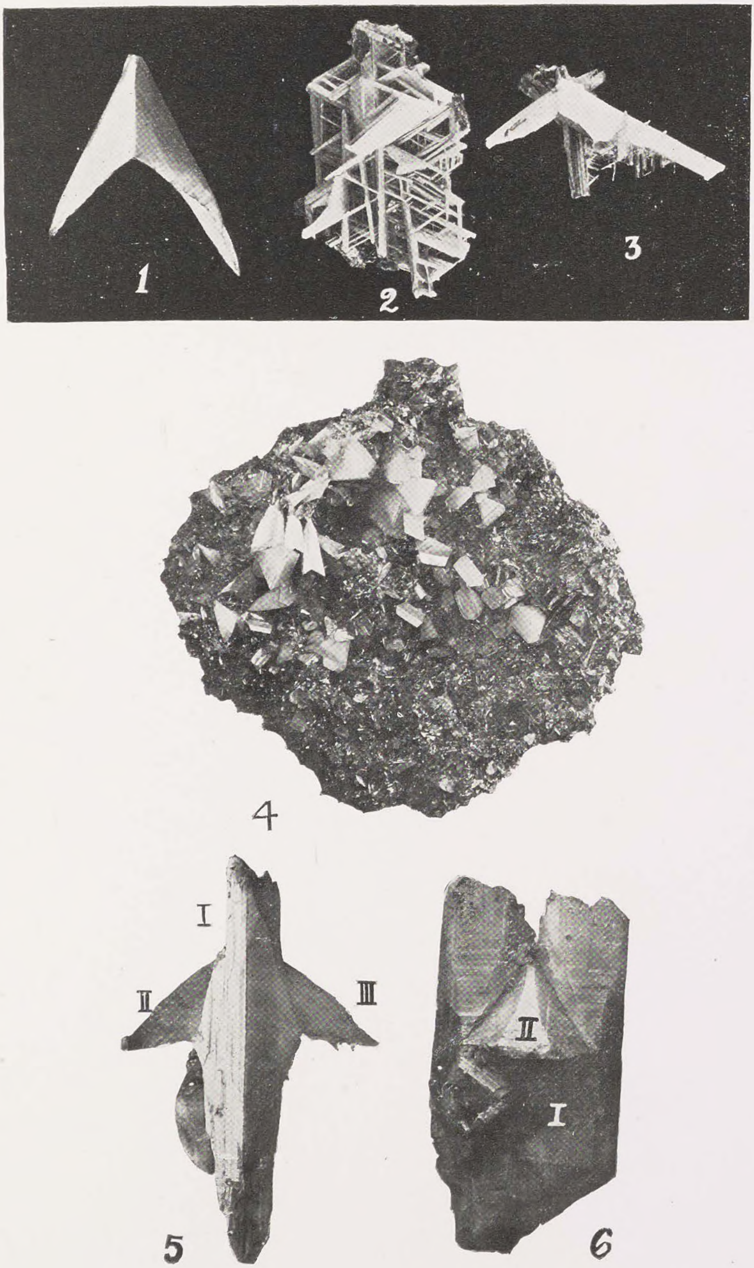

C. Clutton, photo., Austr. Mus.